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managing our environment

a report on ways agricultural research fights pollution

THIS REPORT deals with a national priority—that of managing our environment. It covers some of the major challenges facing scientists and regulatory officials working in agricultural research. These challenges are manifold and complex, and the scientific efforts to meet them are at times inadequate. However, some of the tools to help manage our environment are available, some are being developed and tested, many others have not reached the drawing board. Certainly not all of these tools will work.

There is no panacea—no quick solution. It will require a national effort by millions of people working together. It is hoped this report will help you as an individual recognize more fully some of the challenges facing all of us—and thereby involve you in "Managing Our Environment."

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Managing Our Environment

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THE PRESENT DECADE will in all likelihood be remembered as the time when people became concerned about the environment. Most of us now realize that nature's treasures must be used more discriminately than they have been in the past if man is to continue to prosper, or indeed survive. The Earth's resources are as finite as the blades of grass in a meadow. There are only so many acres of land, so many gallons of water, so many cubic feet of air. We cannot manufacture these basic requirements of life. Unfortunately, we—including agriculture—are still exploiting them. It behooves us to manage our resources better than we have.

There is bound to be disagreement on how to go about it. After all, a good many of our present environmental difficulties are traceable to man's earlier efforts to change his environment. Caves were uncomfortable, so man built houses. The houses got cold; so he lit fires. Sewage accumulated; so he dumped it into the nearest river. All of these efforts were doubtless hailed as milestones in environmental management, as in the short run they were. Eventually, however, they led to widespread pollution of soil, air, and water.

No one can predict with certainty that a given technological innovation will be without drawbacks. Persistent pesticides are an example. Nevertheless, it is to technology that man must look for the answers to environmental problems. Society has grown too complex to permit a mass movement back to the simple life.

History offers the environmentalist some guidance in his choice of technologies; some past scientific efforts have contributed to environmental quality, some have not. Overall, the agricultural scientist's record in this respect has been good. And through diligent application of agricultural science, some of our environmental problems—suburban erosion or stream siltation, for example—can be solved.

But new ideas will also be needed, particularly concepts that are broad enough in scope to help solve future as well as current environmental problems. We are reorienting much of our research effort—primarily within the limits of present budgetary allotments—to develop this new knowledge.

Of foremost importance in any scheme to manage the environment is public safety. We must be able to see to it that food, water, and air will be free of harmful contaminants. Agricultural chemicals, for example, have provided man with a shortcut to large-scale production that could eliminate hunger. Some of these chemicals, however, particularly the more persistent pesticides, also contribute unwanted substances to the environment. In those cases where we are unable to find ways to use chemicals safely with respect

to all environmental values, we will need to replace chemicals with other production techniques. This is the aim of scientists who are working on biologic control of insects.

Another concept that is central to a well-managed environment is recycling. We must learn to reuse things—sewage, tin cans, old car bodies. Here, too, agricultural scientists are making progress. In Phoenix, Ariz., they are putting city sewage effluent through soil filters to purify the water, thus opening up the possibility of a new, practical way to increase municipal water supplies. Another team of scientists at Beltsville, Md., is raising housefly larvae on chicken litter, feeding the larvae to chickens, then using the resulting litter to grow more larvae. In California, tomato processing is being done with mobile units in the fields where the tomatoes are grown, and the residue from the processing spread on the fields to replenish the soil.

Still another important aspect of environmental management involves resource inventory. Agricultural scientists have already compiled much data on the state of the environment, through such methods as soil sampling and through their observations of plants, animals, and insects. Future resource inventory will require more massive efforts. To this end, researchers are studying the technique of remote sensing—automatic recording of data on the Earth's resources from airplanes or from orbiting spaceships. Remote sensing would give man a current and worldwide inventory of resources of unprecedented accuracy.

These are some of the practical aspects of environmental management. But our environment should provide us with more than the essentials of life. Agricultural scientists are also working on ways to make the environment a source of beauty and inspiration. Specialists in horticulture are breeding plants that will add color to roadsides and city streets. Plant explorers travel throughout the world looking for plants that will grow in the less hospitable climates of the United States.

All of these topics—safety, recycling, resource inventory, aesthetics—and many others are touched upon in the series of articles that follow. The public has demonstrated its interest in the environment. This book is an effort to encourage that interest, and to invite support of individuals to take part in the struggle to preserve the quality of our environment.

George W. Irving, Jr.

George W. Irving, Jr., Administrator
Agricultural Research Service

Protecting Land, Water, and Waterways

MAN CANNOT outlive Nature's gifts of land, water, and waterways. Yet today we exhaust and deplete these natural resources at a rapid rate. Some see an exploding, exploitive population threatening the very springs of life itself.

In agricultural research, our concern is to protect our land from erosion and our water resources from pollution. We know that soil erosion caused by the runoff of water from cropland and livestock operations is responsible for most of the agricultural pollution of our water resources.

The amount and kind of precipitation affects the nature of land erosion. A heavy rainstorm can dislodge great masses of soil and other material. And as this water moves across the land it causes sheet and gully erosion.

The average annual precipitation in the United States is about 30 inches. But the variation between areas is great. For example, little or no rain falls in Death Valley, but in parts of Puget Sound the annual rainfall is more than 120 inches.

About 30 percent of the water from annual precipitation finds its way into rivers, lakes, and ocean. Of the remaining 70 percent that soaks into the soil, less than 1 percent percolates down to ground water level. The rest evaporates or is used by growing plants.

Many factors besides the amount of rainfall determine the amount and kind of material that water picks up. These include the type of soil, steepness of the slope, vegetative cover, amount of fertilizer and other chemicals in the soil, and measures taken to control runoff. When water moves over and through the soil, it may transport sediment, plant nutrients, animal wastes, dissolved salts, pesticides, and other material that can pollute our water supplies.

Sediment

Sediment is composed primarily of clay, silt, sand, rock, crop residues, and other material that can be transported by flowing water. Water picks up this material and deposits it in our ponds, lakes, reservoirs, and streams. Construction sites can be a major contributor of sediment. For example, a 1½-acre construction site near Baltimore, Md., was observed to yield 219 tons of sediment per acre per year. Erosion from cropland can be as serious.

As the Mississippi River flows to the Gulf of Mexico, it picks up sediment from strip mining in West Virginia, cornfields in Iowa, wheatfields in Montana, rangelands in Colorado, and the Badlands in South Dakota. Its annual flow of 450 million acre-feet of water carries nearly 500 million tons of sediment to the Gulf annually. This much silt is equal to the topsoil from nearly 500,000 acres.

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Sediment from soil erosion is a serious contributor to water pollution.

There are nearly 800 million acres of land in the Mississippi drainage basin of which 292 million acres are in cropland. It is apparent that erosion from cropland and the banks of streams contributes a large part of the sediment carried by the Mississippi River. Also, erosion from highways and construction sites is increasing rapidly.

The sediment produced in the Mississippi basin annually is about 390 tons per square mile, but the production varies among the tributary streams from 9 tons to 10,000 tons per square mile per year. The agricultural areas that produce the most sediment are those that are unprotected by vegetative cover. And large contributions of sediment can be credited to construction of forest roads, land made bare by forest fires, overgrazed rangeland, unprotected roadbanks, exposed streambanks, highways, and construction sites.

Besides clogging streams and lakes, sediment increases the cost of water clarification in municipal filtration plants. Industries such as food processing and textile manufacturing must have water that is free of sediment. Also, sediment that includes large amounts of organic matter often lowers the oxygen content in water, which may cause fish to die in streams and lakes. Proper erosion control is the best way to solve most sediment problems.

In nonagricultural areas, the sediment that comes from erosion can be reduced by such practices as—

- Covering construction slopes with inexpensive mulch.

• Planting grass on the banks of waterways or leaving the natural cover on the banks of waterways.

• Protecting trees during construction.

On agricultural land, changing cultivated fields from row crops to small grain may reduce soil loss from erosion by as much as 80 percent. Such practices as mulching, stripcropping, and contour cultivation are highly effective in reducing soil erosion. Graded cropland terraces may reduce erosion in fields by 75 percent and when used with crop rotation, mulching, and minimum tillage, they may reduce erosion to practically nothing. And when cropland is converted to pasture or woodland, soil erosion can be reduced by 90 percent or more.

In an experiment in Riesel, Texas, good conservation practices, including improved crop rotation, permanent grass, and graded cropland terraces, were used on a 132-acre watershed. The sediment yield from this watershed was 88 percent less than from an adjacent 176-acre watershed on which no conservation practices were used. On paired watersheds of 400 acres at Rosemont, Nebraska, soil conservation practices have reduced sediment yield by about 50 percent.

Animal Wastes

Erosion imposes other penalties besides washing away soil. It also picks up waste material from feedlots, barnyards, and poultry waste disposal areas and carries it into streams and lakes. When this organic matter gets into the streams and lakes, it depletes the oxygen supply in the water. This oxygen deficiency can destroy fish and other aquatic life. For example, Kansas has reported several major fish kills in past years that were attributed to runoff from feedlots.

Carbon dioxide produced by the decomposition of animal wastes in runoff from feedlots, along with phosphorus and nitrogen, may increase algal growth in

Contour cultivation of cropland and other soil conservation practices help control soil erosion.

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streams and lakes. Then as the algae die and decompose, the oxygen supply in the water is depleted, and the water becomes "dead." (For a discussion of disposal of animal wastes see section on "Management of Farm Wastes" in this report.)

Finding ways to prevent depletion of the oxygen supply in water is a primary problem in protecting our streams and lakes. Oxygen depletion is measured by the biochemical oxygen demand (BOD) of the organic wastes in the water. BOD indicates the amount of oxygen required for the oxidation of the organic matter.

BOD is expressed in the amount of oxygen the water will absorb in a 5-day period at 68° F. Water that absorbs no more than 1 part per million (p.p.m.) is considered very pure; 3 p.p.m. means fairly clean water; but water that absorbs 5 p.p.m. or more of oxygen is of doubtful purity.

The waste from a pigpen has a BOD as high as 50,000 p.p.m. Wastes from barnyards and feedlots usually vary in BOD from 100 to 10,000 p.p.m., depending on dilution of the waste and the degree of deterioration. Untreated municipal sewage has a BOD of about 100 to 400 p.p.m. Public health authorities object to runoff entering streams if it is more than 20 p.p.m. in BOD. This means that if these wastes enter a stream already low in dissolved oxygen, they must be highly diluted or they will completely exhaust the dissolved oxygen in the stream.

More must be done toward solving the problems of animal wastes in water resources. Scientists are working to develop feedlot management practices that will prevent runoff from entering streams. Another approach might be the reuse of effluent from animal wastes and sewage to irrigate cropland.

Plant Nutrients

Besides carrying animal wastes into our water resources, soil erosion also robs our land of plant nutrients and deposits them in our streams and lakes. The 500 million tons of sediment that moves down the Mississippi River toward the Gulf of Mexico each year carries about 5 million tons of undissolved plant nutrients adsorbed on the sediment particles. In addition, this water may carry as much as 50 million tons of dissolved plant nutrients. In the United States, the total amount of sediment that washes into streams each year may approach 4 billion tons. This results in serious plant nutrient losses from the soil.

Statistics show that in fiscal year 1967, about 15 million tons of plant nutrients were applied to soils in the United States —6 million tons of nitrogen, 4.3 of phosphate, and 3.6 of potash. These figures have led some to conclude that plant nutrients applied to the land are the source of the nutrients that cause algae and other water plants to grow and pollute our streams and lakes. This is true in some areas. However, where good soil and fertilizer management practices are used, fertilizers from cropland contribute only minor amounts of plant nutrients to water pollution.

Many herbicides have been developed to control water plants. Some have such a narrow range of effectiveness that they can destroy one plant species without harming other species of the same genus. However, the multiple uses of water make it difficult to generalize about what herbicides should be used to control water plants. Each body of water must be considered separately.

Phosphorus

Phosphorus is often considered the most serious contributor of plant nutrients to the growth of algae in water. These plants grow if the water contains only 0.1 p.p.m. of phosphorus.

Phosphorus losses from cropland usually are adsorbed on eroded soil particles.

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Excessive growth of algae and other water plants produces dead streams and lakes.

In this form, it contributes little to the phosphorus content of water. In fact, certain sediments may actually remove dissolved phosphorus in some waters. Metropolitan sewage, on the other hand, contains large amounts of dissolved phosphorus that is readily available for the growth of algae and other water plants. The phosphorus in metropolitan sewage effluent amounts to about 2 pounds per person per year. This phosphorus comes largely from human wastes and household detergents. The sewage effluent from a city of 1 million people carries about 1,000 tons of phosphorus a year that is available for algal growth. This is enough to grow algae in 3.5 million acre-feet of water.

Experiments by the Missouri Agricultural Experiment Station have shown that large amounts of phosphorus can be lost from fields by soil erosion. Where corn was grown continuously, 18 pounds of phosphorus per acre per year was washed away by erosion. That means that more phosphorus was lost by erosion in a year than the corn plants would have used to produce a 75-bushel crop.

Even where crop rotation was practiced, 6.2 pounds of phosphorus per acre was lost by erosion. Where grass was grown, only 0.1 pound per acre was lost

simply because grass gives such good protection against soil erosion. The remedy then is intensified use of soil conservation practices to lessen the runoff of water and sediment from farms.

Nitrate

Nitrogen fertilizer has received its share of criticism as a pollutant of waterways. It is responsible for some of the nitrate found in water, particularly in the drainage from irrigated fields. Where efficient fertilizer practices are followed, however, fertilizer nitrogen is not a serious contributor to water pollution.

Studies at the University of Missouri showed that nitrate found in ground water did not come from fertilizer on the land. Some of the nitrates in ground water came from natural nitrate deposits and from soil organic matter. Other nitrates came from livestock feedlots.

More than 30 years ago, the U.S. Geological Survey found that nitrate accumulates naturally in fairly large quantities in certain areas. In fact, nitrate accumulations were found in soils of geological formations in all of the 11 western States and many of the States of Appalachia. Studies in Colorado back near the turn of the century showed large accumulations of nitrate on the plains of Colorado before man was ever there.

Nitrogen fertilizers at times cause high nitrate accumulations in food plants. Many kinds of plants, such as spinach or beets, may take up high levels of nitrate even when the soil is unfertilized. Nevertheless, under certain climatic conditions when the soil is fertilized, such crops as corn or sorghum may accumulate large amounts of nitrate.

Cooperative research at Purdue University has shown that considerable nitrogen is lost to surface runoff if ammonium nitrate fertilizer is broadcast on the soil before a runoff-producing rain.

Scientists at the California Agricultural

Engineers check a recharge basin used to renovate sewage effluent.

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Experiment Station have studied the nitrogen and phosphorus content of drainage from irrigated fields in the San Joaquin Valley. There was practically no phosphorus but the nitrogen content of the drainage varied from 1.8 to 62.4 p.p.m.

In one California area, 150 acres was planted in cotton and rice under irrigation, and 23,500 pounds of nitrogen was applied. Of this, 14,800 pounds was lost in the drainage water. These tests show that improvements need to be made in the efficiency of nitrogen used under irrigation. In some cases, too much fertilizer may be used on cropland, but when good fertilization and water management practices are followed, nitrate in ground and surface water can be greatly reduced.

Reuse of Sewage

It has been predicted that multiple reuse of water will become necessary by 1980 because the use of water by that time will equal the supply available from streams and ground water. The reuse of municipal sewage effluent is the most likely source of water to supply these additional needs. One of the potential users of sewage water is irrigated agriculture because large quantities of water are needed for irrigation, and the plant nutrients in sewage are valuable as fertilizer for crops.

Sewage that is conventionally treated can be used for irrigation only on nonedible crops and in remote areas. Where a variety of crops is grown near population centers, sewage needs further treatment to remove disease germs and material that would cause unpleasant odors. The water could then be used without causing a nuisance or creating a hazard to public health.

Recent studies at Phoenix, Ariz., show that sewage can be effectively renovated when used for ground water recharge. In this system, the effluent from a conventional sewage treatment plant is run into basins dug in the surface of the soil. The effluent then percolates through the soil to the ground water table below. When it reaches the ground water table, it can be used to fill surface ponds or reservoirs.

During this process, and particularly as the water percolates through the first 5 to 10 feet of soil, the quality of the waste water is tremendously improved. Bacteria collect in the soil beneath the basins and completely decompose the biodegradable material. Disease germs also are effectively removed in the zone beneath the basins, and depending on the soil, significant reductions are made in phosphorus and other minerals.

Salinity

Salts and minerals occur naturally in water and more may be added by drainage from irrigated land. Industrial and acid mine wastes are other sources of salinity in water. Acid mine drainage, especially in some parts of the Ohio River Basin, has already seriously damaged water quality and may destroy aquatic life.

Rivers in arid and semiarid parts of the country pick up considerable salt from the land through which they flow. The Colorado River at Yuma, Ariz., carries more than 1 ton of salt per acre-foot of water. Tests of Pecos River water in Texas during low flows have shown more than 15 tons of salt per acre-foot of water.

Salinity is a serious problem in the irrigated lands of the Southwest. Samples of drainage from these lands have shown a salt content of up to 25 tons of salt per acre-foot of water.

The irrigation water used in fields always carries some dissolved salt. Plants extract some of the water from the irrigated fields but leave most of the salt in the soil. Also, water that evaporates from the soil is pure water causing more salt to accumulate in the soil.

For irrigation agriculture to survive, this accumulation of salt in the soil must continually be leached out with applications of water in excess of plant requirements. The salt moves deep into the soil, into the ground water, or into the drainage system as it is leached out. Thus, the salt in drainage water includes both native salt and that brought in by the irrigation water and accumulated in the soil through evaporation.

An irrigated area must have a favorable salt balance. Salt leaving the soil by drainage must equal or exceed that received in the irrigation water. Thus the drainage water is of inferior quality because of the excess salt. But scientists are determining how soil conditions, climatic factors, and salt tolerance of plants affect the use of salty irrigation water and other water of inferior quality.

Irrigation drainage water usually is returned to rivers but it may be so salty that alternative methods of disposal should be considered, such as reuse on salt-tolerant crops. Some crop plants are 10 times as salt tolerant as others. Therefore, the drainage water may be too salty for general use but it could be used for crops with especially high salt tolerance.

Bermudagrass pastures and seed crops of some other grasses can be grown with water too salty for general agricultural use. And further concentrated use of the drainage water, by using it on a second salt-tolerant crop, may be another step toward temporarily disposing of salty waste water. But this is not the final solution to the problem; the excess salt must be removed from the soil sooner or later when the accumulation becomes too great even for salt-tolerant crops.

Research is underway on more efficient use of irrigation water. Application of water must meet the needs of the plants, and at the same time, maintain the desired salt balance in the soil. Therefore, improved irrigation efficiency will conserve water, decrease the amount of drainage water, and reduce the amount of

This grapefruit tree died from too much salt in the soil. BN-36473

salt that must be removed from crop fields.

Pesticides

When used properly, pesticides have brought great benefits to man and his environment. And when misued or carelessly used, they have harmed wildlife and polluted the environment.

Although scientists have high hopes for the eventual development of effective alternative means of pest control, chemicals must be used for the present. Users of pesticides in agriculture must be aware, however, of the problems and the hazards that pesticides can create for man and his environment. Some of the alternative methods of controlling pests are discussed in this report in the section titled "New Ways to Fight Pests—Alternates to Pesticides."

The public has a right to be concerned over possible poisoning of the environment. For example, DDT can cause thinning of eggshells in ducks and falcons. Pesticides from the air, water, and soil may be absorbed and concentrated in the bodies of organisms. The concentration in the tissue is frequently increased as one species feeds on another and passes the pesticide from one link to another one higher in the food chain. In this sequence, some predators such as birds and fish may be exposed to levels several thousand times the concentration in the physical environment.

Some of the work that scientists are doing to prevent residues of pesticides in soil and water include—

- Development of improved pesticides that do not persist in the environment and improved methods of applying them.
- Better control of sediment runoff to reduce pesticide accumulation in streams and lakes.
- Development of methods for the faster degradation of persistent pesticides.
- Control of the drift of pesticides into the air, which is a major pathway of pesticides into the environment.

Research for Tomorrow

Because many potential agricultural pollution problems are related to soil loss and water movement, management practices that prevent erosion and make efficient use of water will minimize these hazards. Good management practices include minimum tillage, mulching, contour strip cropping, terracing, improved drainage, and others. Soil and water research is continuing to develop and evaluate new conservation practices that can be adapted to the increased use of large multirow farm equipment and intensified farming operations.

In addition, research is developing methods that will make more efficient use of fertilizer, and at the same time, minimize potential losses to water erosion. Other practices are being developed to control the movement of pesticides in soil, water, and air so that residues will not become environmental contaminants. Similarly, the control of water movement over and through the soil will help control pollution from animal wastes. ■

Management of Farm Wastes

FIFTY THOUSAND beef cattle fattening on a feedlot in Texas . . . big, silver dairy barns glistening in the Wisconsin sun . . . acre after acre of Kansas wheat and Iowa corn. Truly, we enjoy the most abundant agriculture in the history of mankind.

But at the same time, we are faced with the problem of what to do about the tremendous amount of waste from that abundance. It poses a serious threat to our environment.

For example, many large cattle feeding operations like the Texas feedlot, originally in rural areas, are now surrounded by suburbia. Odors, dusts, insects, noise, and polluted runoff water from the lots limit the use of adjacent land for either housing or recreation. And the pollution may be running into nearby streams, rivers, ponds, or lakes, ruining the fishing and swimming.

Many large dairy and poultry operations are in the same position.

Yet livestock waste is just one kind of farm pollutant endangering our water, land, and air. Others include surplus pesticides, the empty pesticide containers, and field crop and orchard residues.

Scientists have solved many complex problems to reach our present level of agricultural production and quality. Now they are tackling the waste problem. They seek ways to reclaim or recycle the material rather than just dispose of it. Not only is a usable byproduct a bonus, but it solves the problem of final disposal and thus reduces the pollution hazard.

Livestock Waste

Livestock waste, including that from poultry, is agriculture's biggest waste disposal problem. Some answers have been found, many others are yet to be found.

Extent of the Problem

Only statistics can fully illustrate the magnitude of the problem.

Livestock produce some 2 billion tons of waste each year. This breaks down into 1.2 billion tons of solid waste, 400 million tons of liquid waste, and another 400 million tons of associated waste such as bedding and dead carcasses.

One dairy cow with an average milk production of 20,000 pounds produces 27,000 pounds of manure a year. Ten thousand beef cattle concentrated on a feedlot produce 200 tons daily. A feedlot carrying 50,000 head has a disposal problem comparable to that of a city of 600,000 persons.

To sum up: The amount of livestock waste produced in this country each year is equivalent to that of a human population of 1.9 billion. As much as 50 percent of this waste may be produced under concentrated conditions.

Accumulations of manure emit offensive odors and dusts into the surrounding area and provide a spawning place for

flies and other vermin. Miniature mountains of the waste can be seen piled beside some larger feedlots because of no economical or satisfactory method of disposal.

When it rains, there is runoff. Unless prevented from doing so, this polluted runoff often ends up in a stream, river, pond, or lake. Some feedlots, in fact, have been purposely located on slopes above streams to induce runoff that discharges into the water.

Some of the runoff may percolate down through the soil to the groundwater level—the source of water for our wells.

Feedlot waste invariably has a high biochemical oxygen demand (BOD) and readily depletes dissolved oxygen in water under aerobic decomposition. If sufficient waste gets into the water, the depletion of oxygen may be serious enough to kill fish and other aquatic life.

The waste also carries nitrogen, phosphorus, and potassium. These fertilizer nutrients promote the growth of algae, other aquatic weeds, and slimes in the water.

How to handle this waste economically yet minimize the pollution hazard? This is the problem facing agricultural scientists.

Current Methods and Research

The processes used to treat municipal sewage are not satisfactory for treating livestock waste. One reason is the cost. Another is the basic difference between the two kinds of waste. Municipal sewage is largely liquid; livestock waste, mainly solid.

Other methods must be used.

Land Disposal

One way to handle the waste is to spread it on cropland or pasture. This practice is probably as old as agriculture itself.

Manure contains many essential plant nutrients, including trace elements not generally found in "bag" fertilizer. When spread on the land, it helps to build and maintain soil fertility, improve soil tilth, and decrease erosion.

Land disposal also favors recycling of the waste. This may be illustrated by a large cattle feeding operation near Greeley, Colorado. This feedlot carries some 90,000 head of beef cattle. The hundreds of thousands of tons of manure produced are spread on 10,000 acres of corn land. Some 200,000 tons of corn are harvested, ensiled, and then mixed with cooked grain and fed to the cattle.

Handling manure in the solid state has drawbacks however. The labor requirement is high and the manure must be stockpiled until time for spreading. Stockpiling of manure not only increases the pollution hazard, but some of the nutrient value may be lost through leaching and bacterial action.

To overcome these problems, agricultural engineers adapted the liquid manure handling system popular in Europe. Basically, this systems calls for flushing the manure into collection pits or tanks and holding it until time for disposal. At that time, the manure-water mixture is spread on the land by tank wagon, through a sprinkler irrigation system, or through irrigation ditches.

Land disposal is not the answer in most cases however. Many feedlot operators have neither cropland or pasture on which to spread manure. Near cities, this method merely transfers the pollution hazard from the feedlot to the field—the problems of odors and runoff remain.

And finally the economic factor. Cost studies indicate that it is cheaper for the farmer to apply bag fertilizer than to haul and spread manure.

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Livestock waste is agriculture's biggest disposal problem. Hundreds of thousands of tons of manure are produced on some large feedlots.

Lagoons

Much research has been done on the use of lagoons to oxidize livestock waste. The results indicate that aerobic decomposition (by oxygen-using bacteria) is more effective in breaking down the organic matter and thus reducing the BOD than anaerobic action (by non-oxygen-using bacteria). However, a combination of aerobic and anaerobic decomposition is the most effective.

Lagoon disposal, like land disposal, permits recycling of the waste. This may be illustrated by a large hog operation near Pendleton, Oregon. The hogwash is collected in lagoons and then distributed over 140 acres of cropland through a sprinkler irrigation system. The waste aids in producing about 10 tons of alfalfa hay per acre. The hay is ground and used for hog feed.

Lagoons have proved a better method of disposal for poultry waste than for livestock waste. In general, however, lagoons have not been too satisfactory. They tend to be underdesigned, overload-

ed, and misused. Too often they discharge fertilizer nutrients into nearby streams, ponds, or rivers, promoting the growth of aquatic weeds. And unless the waste is subsequently removed and spread on the land, there is complete loss of the value of the nutrients.

Agricultural engineers are testing a way to utilize the fertilizer nutrients in waste-disposal lagoons and at the same time purify the runoff from the lagoon to prevent the pollution of nearby waters.

On a Maryland farm, the engineers built a series of three basins downhill from a lagoon and planted them to grass. The lagoon runoff flows through the basins and the grass (which grows hydroponically nourished by the nutrients in the runoff) strains out the solid matter. In effect, the grass-covered basins act as a mechanical filter and chemical scavenger to purify the runoff. The grass can be harvested as forage for livestock.

Northern States, such as Minnesota and North Dakota, have no serious pollution problem during the winter months. The severe cold preserves the manure, limiting decomposition, odors, and runoff. But the spring thaw can bring a major problem unless the manure has been handled properly.

In cooperative research at the University of Minnesota, agricultural engineers are testing modifications of the Pasveer Oxidation Ditch as a year-round method of handling livestock waste. This method —developed in Holland to handle municipal sewage—calls for mechanical stirring and aeration of the waste to supplement natural oxidation. The results to date indicate that manure can be handled satisfactorily up to a year. Once a year the contents of the ditch would be disposed of on cropland or in a lagoon.

Composting

Farm wastes have been composted for thousands of years. Most home gardeners now practice some kind of composting.

Composting reduces raw organic matter to a loose, friable, odor-free soil additive. And, very importantly, it reduces the volume.

Poultry manure has been composted with some success. The usual method is to expose the manure to the air in windrows in the field, turning it periodically.

The scientists also tried on-site composting—in the poultry house. They inoculated the poultry litter with selected micro-organisms to aerobically decompose the resulting manure. The method proved relatively inexpensive, provided an odorless and fly-free environment, and kept dust to a minimum.

In cooperative work at the University of Maryland, agricultural engineers are working on the composting of large amounts of livestock waste. They report success in digesting half-ton batches of dairy cow manure and bedding to a relatively odorless material. The volume was reduced about 30 percent, and the weight about 50 percent. Further volume reduction could be obtained by compaction, and further weight reduction by drying.

Temperatures generated inside the compost pile during composting are usually high enough to kill insects, their eggs and larva, and many weed seeds. For this reason—plus the nutrient value—composted material is a desirable soil additive. At present, however, there is a very limited market for the material—local sales only. Unless a large market develops, composting would not be a profitable waste-disposal method. On the other hand, it is one of the more economical methods of disposal and may be practical from that standpoint.

Dehydration

A few large feedlot operators dehydrate their manure, bag it, and sell it to home gardeners. Large amounts must be handled to justify the investment and

operating costs.

Dehydrated poultry manure is not too acceptable as a market product. When wetted, it re-emits the characteristic poultry-manure odor.

Control of Feedlot runoff

Effective control of feedlot runoff could greatly reduce the pollution hazard to streams, rivers, and other bodies of water. In cooperative research at the University of Nebraska engineers set up two experimental systems—similar in purpose but different in management and design—to study the control of feedlot runoff. The results obtained from one of the systems justified setting up prototype installations of it for further evaluation.

In the more promising system—called the "continuous flow system"—the runoff is diverted into a channel containing three wooden dams. The dams slow the runoff, allowing the solids to settle. The liquid waste seeps through the dams and flows into a detention pond. The system is designed so that the solids can be removed with conventional feedlot cleaning equipment.

Future Research

Continuous improvement in the methods and systems of handling and disposing of livestock waste is essential to minimize the pollution hazard. Future Federal, State, and industrial research needs to stress or to investigate the—

- Development of basic methods and systems that, with minimum adjustment, could be adapted to any type enterprise in any part of the country. Geographic, climatic, and enterprise differences tend to limit the applicability of some methods and systems.
- Acquirement of more information on the characteristics and chemical nature of manure and the effects of feeding and management practices on these factors. Such information would prove useful in developing potential uses and methods of disposal of manure.
- Identification of the odor producing organisms in manure and development of means to destroy them.
- Treatments of manure that would tend to discourage flies and other vermin from using it as a breeding ground.
- Use of manure as a culture medium for the propagation of organisms antagonistic to plant diseases and pests. If practical, this might make land disposal more practical and more profitable.
- Use of livestock waste in combination with industrial waste to reclaim marginal or badly eroded land. Cinders, fly ash, and other industrial waste might improve the structure of some soils by providing better aeration of the root zone. Livestock waste would provide some fertility and might appreciably improve the structure of intractable soils.

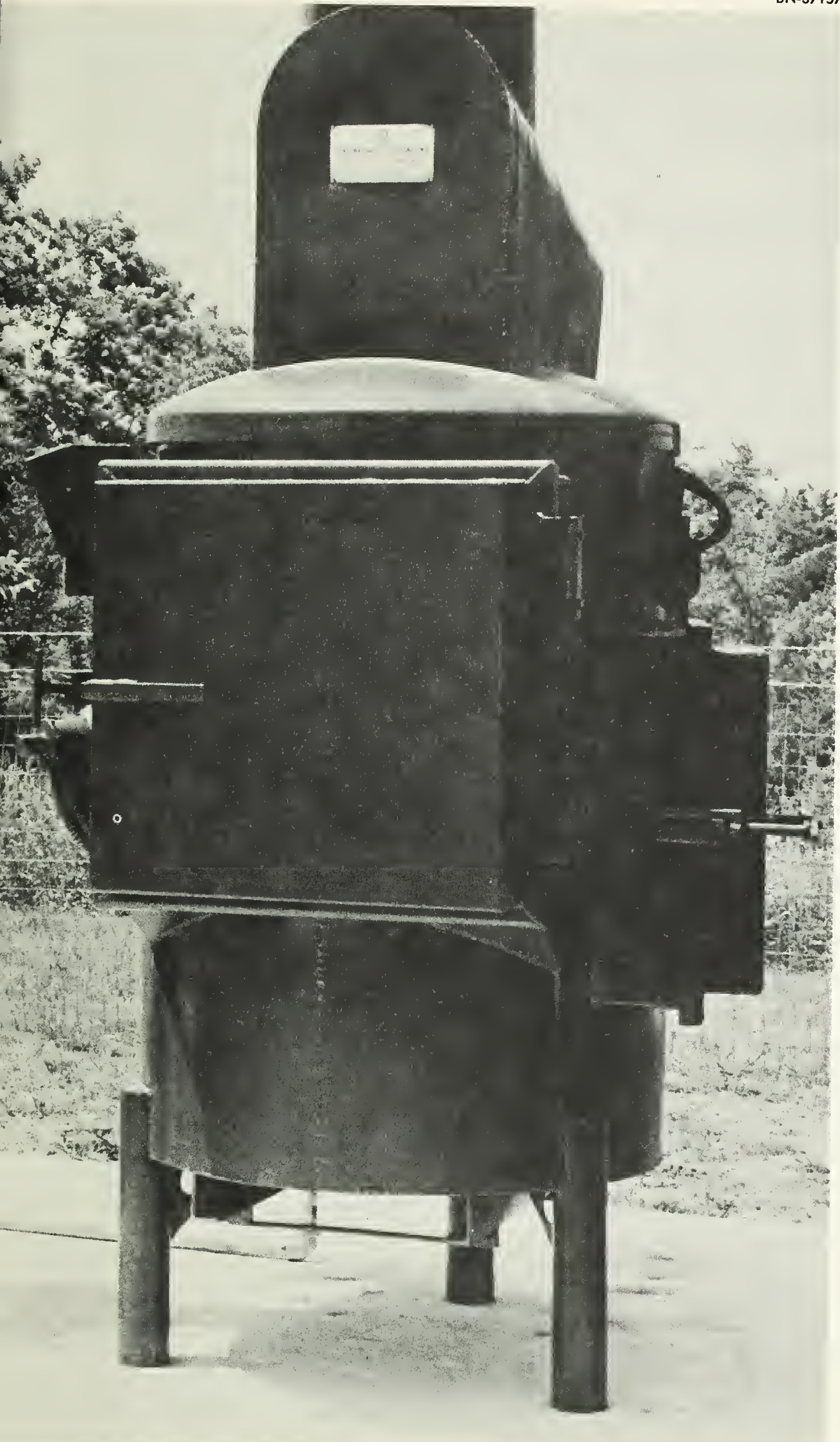
Surplus Pesticides and the Empty Containers

Few persons argue the effectiveness of pesticides in agriculture. These chemicals enable farmers and gardeners to control insects, weeds, and diseases that would otherwise destroy or greatly damage food crops and ornamental plants.

But most persons are deeply concerned about the potential danger to our health and environment by the use of pesticides. All pesticides are poisonous to some degree; some are highly toxic.

Federal and State scientists monitor our soil, water, crops, livestock, and food against the overuse of pesticides and the buildup of unsafe levels of residue. And they also seek to develop new, less toxic pesticides and biological methods of controlling plant pests.

But that's not enough. Pesticide users must share the responsibility for protecting our health and environment. They must make sure that surplus pesticides



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Controlled incineration may prove to be an effective way to dispose of surplus pesticides and the empty containers. A prototype of the proposed incinerator is now being tested.

and the empty containers are disposed of safely and properly.

One of the most common causes of pesticide accidents is the "empty" container. No pesticide container is ever completely empty—there is always some active material clinging to the inner surface.

"Empty" pesticide containers can be an "attractive hazard" to children and pets. Barrels and drums converted into livestock feed troughs, water storage tanks, or raft floats become sources of contamination for feed and water. If discarded in the line of water runoff, the containers can contaminate streams, rivers, ponds, and lakes.

The Department of Agriculture sponsored a major conference last summer on handling and disposing of surplus pesticides and empty pesticide containers. It was attended by representatives of Federal, State, and local governments and of business and industry.

The conferees noted that burning is not a good method of disposal and is no longer recommended. The particles and vapors generated in burning pesticide containers can pollute the air and endanger people, animals, and plant life. In many areas, local ordinances may prohibit the burning of empty pesticide containers.

Burning has not been eliminated as a possible future method of disposal, however. In fact, scientists feel that a combination of controlled burning and burying might be developed as the most effective method. The surplus pesticides and empty containers would be burned in a specially designed incinerator and the ashes would be buried.

Under an ARS grant, scientists at the Mississippi Agricultural Experiment Station are testing a prototype of the proposed incinerator. Special design features of the unit include a "scrubbing" system for cleansing the gases produced in burning the chemicals and containers.

Under a previous research grant, the scientists determined the temperatures required for complete or almost complete combustion of different pesticidal chemicals. Of the 20 formulations tested, three showed 99 percent or more combustibility at the relatively low temperature of 250° C. (482° F.). All but six approached complete combustion—95 percent or more—at 800° C. (1,472° F.). At 1,000° C. (1,832° F.), these same six still yielded 10 percent or more uncombustible residue.

From the results, the scientists assumed that temperatures at or near 1,000° C. would be sufficient to degrade 99 percent or more of most current pesticidal formulations.

Some ingredients in pesticidal formulations—for example, heavy metals—would not be combustible. Other treatment would be necessary for complete degradation.

The scientists also tried degrading or decomposing pesticides with chemicals and micro-organisms. While the results were less satisfactory than by incineration, these methods might prove effective as pre-incineration or post-incineration treatments. They might be used to soften or partially degrade the chemicals before incineration or to complete degradation after incineration.

Another objective of the research is to determine of what materials pesticide containers should be made to facilitate disposal by incineration.

Plant Residues

Plant residues contribute to pollution when left on the ground and when burned.

When left on the ground—as mulch, for example—residues harbor diseases and insects that may affect subsequent crops. Diseases known to be transmitted through residue left on the ground include late blight of potato, cotton verticil-

lium wilt and bacterial blight, apple scab, and brown rot of stone fruits. Insects that overwinter in residue include the pink bollworm and the European corn and sugarcane borers.

Waste or residue from grasslands, grainfields, rangelands, and orchards is sometimes burned to rid the land of the material or to control a disease. Such burning emits smoke, hydrocarbons, and other pollutants into the air.

For example: Some 900,000 acres of grass are grown for seed each year, resulting in about 2 tons of residue per acre. About one third of this acreage is burned each year as a sanitation measure. This burning releases some 50,000 tons of carbon and ash particulate into the atmosphere.

In western Oregon, the residues of grass seed crops are sometimes burned to control the blind seed disease. At present, this is the only practical method of control.

Other residues or wastes burned include fruit tree prunings, rice straw, barley straw, and range brush. (Interestingly, in test burnings, such materials produced less hydrocarbons per ton of fuel consumed than automobile exhaust.)

The major use of crop residue is as mulch in stubble-mulch farming. Less important uses include as bedding for livestock and poultry and in the manufacture of corrugated cartons, insulating boards, and similar products.

As mulch, crop residue protects fallow land against wind and water erosion. But at the same time it harbors plant pests and affects the chemical, microbiological, and physical character of the soil. In some cases, it may depress crop yield.

More knowledge is needed on mulch if we are to fully realize its benefits without undue loss from the adverse effects. For example:

- During the microbial decomposition of crop residue, great changes occur in the microbial population in the soil. Plant pathogens are sometimes suppressed or eliminated during this surge of microbial activity. If the scientists can determine why, perhaps they can treat or amend the residue to increase this biological control of disease organisms.
- Crop residue may have yet unsuspected harmful or beneficial effects on crop growth. More knowledge on the chemistry and biological effects of residue decomposition may reveal such effects. Eventually, the scientists may be able to manage the decomposition process so as to reduce the harmful effects and stimulate crop growth.

The burning of plant residue or waste generally creates a serious air pollution problem at least in the immediate area. However, in many cases, this is the only practical way to get rid of large amounts of the material. New, economical ways need to be developed.

Plant breeders are trying to develop new, short-straw varieties of cereal grains without sacrificing yield. Such varieties will mean less residue left in the field after harvest.

The brush residue left after clearing rangeland might prove useful in the restoration of grassland. It can be spread over newly seeded areas to help reduce moisture loss.

Radioactive Fallout

In a nuclear war, our agriculture could be destroyed or seriously crippled. We must be prepared to provide at least the barest essentials—food and water.

But there is a more immediate hazard —the possible contamination of our water, land, and air by current nuclear activities. Fallout from nuclear weapons testing is the chief concern here.

USDA research on radioactive contamination is directed toward meeting both of these emergencies. Carried on in collaboration with other Federal and State agencies, the work covers many aspects of the

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Deep plowing to a depth of 2 feet or more is one of the ways tested to decontaminate land after radioactive fallout. Other methods include scraping off the top 2 inches of soil and vacuuming and sweeping the soil surface.

problem. The major effort is concerned with returning the land to use after contamination.

Nuclear fallout contains many radioactive substances. Of particular importance—or danger—to our health are strontium-90, cesium-137, and iodine-131. Traces of these contaminants may eventually show up in plant or animal products unless decontamination is undertaken.

Radioactivity cannot be destroyed. The only solution is to remove the contaminated material. In their research on the cost-effectiveness of various methods of decontaminating land, agricultural engineers found that—

- Removal of a crop removes only a small percentage of contamination because most of the fallout falls onto the soil surface. This method would be effective only in cases of low contamination or as a preliminary treatment for some other method.
- Removal of a sod or mulch removes more contamination than removal of a crop. However, rain, which might occur after fallout, would reduce the amount of contamination removed.
- Scraping off the top 2 inches of soil is the most effective method. However, this method may be impractical and too expensive for large areas. Safe disposal of the dirt removed would be a major problem.
- Vacuum sweeping and brushing of the soil surface moves the minimum amount of soil, but this method is slow because the machines used are narrow and repeated sweeping is necessary.
- Deep plowing to a depth of 2 feet or more significantly reduced the uptake of radioactive material by crops in silty soil. And the addition of a chemical root inhibitor (sodium carbonate) to the contaminated soil reduced the uptake even more. Deep plowing may increase crop yield in some soils; reduce the yield in others. It can be done only once—a second plowing would return the contaminated soil to the surface.

Scientists are also studying the effects of radioactive contamination on plants and animals. For example, at Oak Ridge, Tennessee, USDA is cooperating with other Federal and State groups in a study of the problem of beta radiation dose to plants. Beta radiation may be the most important source of radiation to plants early after fallout when many radioactive particles are still on the plant surfaces.

The scientists also want to know how to reduce the levels of contamination in plant and animal products and how to remove the contamination. Studies have been made or are now underway on the removal of contamination from fruits and vegetables during processing, the separation of strontium-90 from wheat flour during milling, and the removal of radioactive fission products from milk by an ion-exchange process.

Much information has been obtained from the research on radioactive contamination. But much more is needed if we are to be able to cope with heavy fallout conditions.

With more data on the duration and effects of retained fallout particles on plants, the scientists can more accurately predict radiation doses to plants and animals.

Faster, cheaper, and more effective methods of decontaminating forage, food, plants, and soils need to be developed. The scientists may find that certain crops are far more easily decontaminated under field conditions than others.

The scientists may eventually be able to breed crop varieties that would not absorb radioactive materials. ■

Recycling Food Processing Wastes

Alchemy's goal, the conversion of baser metals to gold, occupied the attention of experimenters during the long centuries of the Middle Ages. Today, the conversion of waste material to useful products, more urgent and more important to mankind than the medieval dream, will spare our environment countless tons of unwanted debris.

Water, a necessary commodity in the cleaning and processing of fruits and vegetables, is also the vehicle conventionally used to dispose of the liquid and solid wastes contingent to the manufacturing process. Sooner or later, these wastes find their way into our rivers and streams. Besides adding to the pollution problem, these wastes turn our waterways into avenues of refuse.

In the face of public awareness and stiffening State and Federal legislation, many processing plants today are threatened with shutdowns. For communities, this would mean a loss in employment and in taxable income. But what if ways can be discovered not only to lessen or even eliminate this waste disposal, but to convert the waste itself into useful, edible by-products?

Scientists are presently conducting meaningful research in this direction. In cooperation with private industry and with designers of manufacturing equipment, they are devising methods to circumvent the waste disposal problem. To individual commercial plants, this research may offer an alternative to either going out of business or making expensive improvements. One success story in point involves the common potato.

Policing Potato Peels

Anyone who has spent time in the Army sharing KP chores knows exactly how large a portion of the potato winds up as peels. Whittling with a kitchen knife will also remind you just how stubbornly a potato parts with its skin.

Commercially, the usual method of processing plants is to soften the skins in a lye solution. Large volumes of water are then employed to literally wash the peels from the potatoes. Naturally, these peels "disappear" with the effluent. Downstream, the full effect of this "disappearance" manifests itself in polluted waters and in declining marine life.

New Federal and State antipollution regulations require a much closer policing of these renegade potato peels. An experimental plant, situated in Aberdeen, Idaho, was erected with funds contributed by the potato industry and a private equipment manufacturer. The perfected method of handling potato peels is called the dry caustic peeling process.

Several steps are involved in the process. First, the potatoes are washed and, while still wet, treated with a hot lye

solution. Small amounts of lye are absorbed by the potatoes' surface area. Next they are drained of excess lye and left to stand for about 5 minutes. Some of this lye is absorbed by the potato skins. While the caustic solution is penetrating, the surface of the potato will be cooling.

Following the holding period, the potatoes are subjected to intense heat from infrared burners for 1 to 2 minutes. This heat activates the caustic and dries the potato surface. After this heat conditioning, the potatoes are processed through a rubber-tipped mechanical peeler which rubs off the treated peel. Finally, the potatoes are washed again.

Although some water is used for washing both before and after peeling, none is needed during the actual peeling operation. Thus, the vehicle for the transmission of the pollutant has been removed. Virtually none of the peel residue escapes with the effluent from the plant. Instead, it is collected separately as a slightly damp material that can be burned or buried. More positively, it can also be adapted as a satisfactory constituent of mixed feed for cattle.

Potato processors dispose of about 500,000 tons of peels yearly. As plants convert over to the new dry caustic peeling process, this pollutant will be reduced and, hopefully, eliminated. The potato wastes can be recycled into a productive byproduct. Cows will browse on peels that once clogged our aquatic highways.

Today, the increasing purity of the Snake River in Idaho demonstrates that environmental deterioration can be reversed. Its waters are beginning to reflect credit on the inventiveness of scientists working in cooperation with the potato-processing industry.

Use of this process throughout the industry promises even greater improvements in this major Western river. The Red River, which flows north into Canada, is another that has numerous potato processing plants where pollution can be alleviated. It is hoped that modifications will make this process applicable to sweetpotatoes as well, and thereby bring its benefits to other parts of the country.

By Reverse Osmosis?

Normal osmosis may be described as a process in which two fluids of different concentrations are separated by a semipermeable membrane. During nature's attempt to produce equilibrium, water from the less concentrated solution flows through the membrane into the more concentrated one.

Reverse osmosis, as one might expect, is exactly the opposite. By applying sufficient pressure to the more concentrated solution, a reverse motion occurs. Now water from the more concentrated solution flows through the membrane into the less concentrated one. The recovery of fresh, drinking water from the salty brine of the sea is perhaps the best known example of reverse osmosis.

Within the cheese making industry is a byproduct called "whey." Nursery rhyme students will remember whey as the delicate treat which tempted Little Miss Muffet. More than fourteen billion pounds of whey are discarded in the United States annually.

This tremendous waste represents almost two-thirds of the volume produced each year in this country by the cheesemaking industry. Considering the fact that whey is edible, rich in vitamins, amino acids, lactose, soluble proteins, and contains half the solids of milk, its loss is tragic. Developing nations of the world would well use this product to fill a void in their peoples' diets. Instead, this whey is often floated downstream as just another hazard to aquatic life.

Many States have already prohibited the dumping of whey into waterways. There is a an alternative. This involves concentrating the whey and then drying it. Unfortunately, for most small cheese-

The possibilities of whey concentration by reverse osmosis were first explored in the laboratory. Here, a food technologist demonstrates the theoretical application of osmotic pressure.

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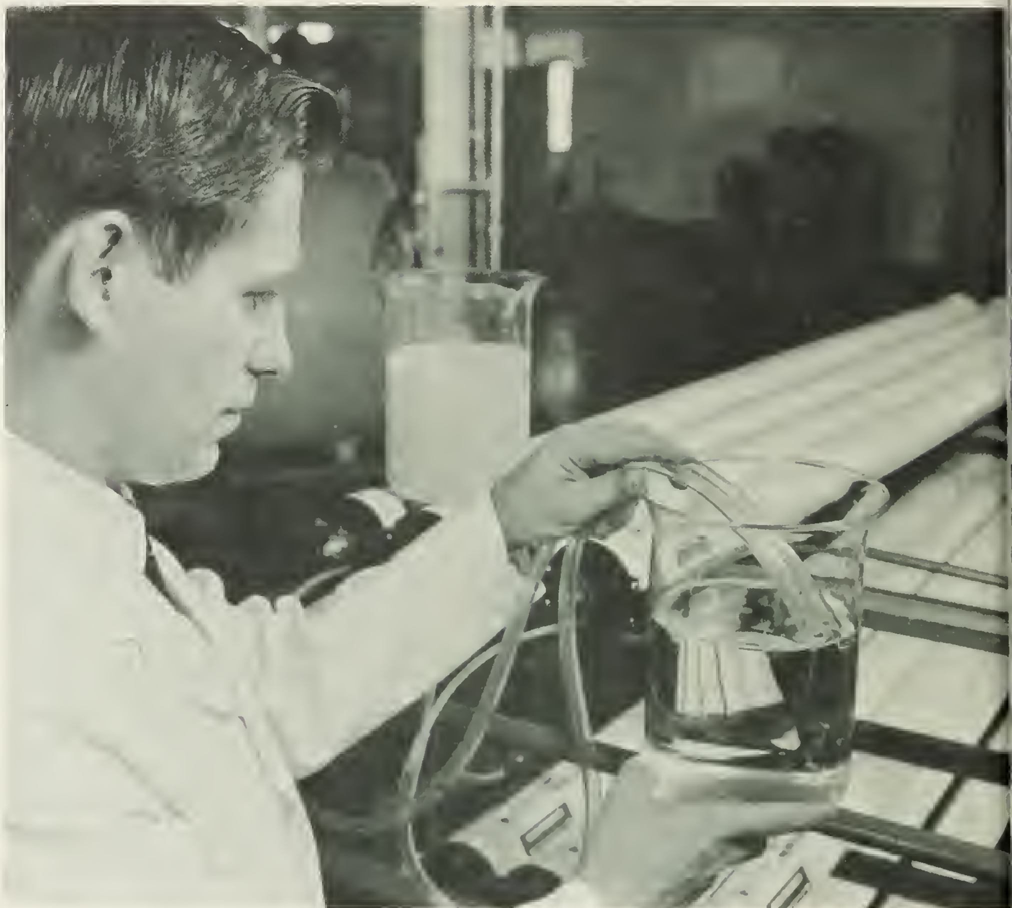

In the factory, the liquid solution has nearly completed the reverse osmosis process. The remaining solids can now be raked together. The final product (far right) of the reverse osmosis process: whey, solid enough to be cut with a knife.

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making plants, the existing methods of treating whey are too expensive. And the expenses for shipping the whey to larger firms are prohibitive.

Now the possibilities for applying reverse osmosis to the whey problem become apparent. Scientists determined that by removing 75 to 80 percent of the water from whey by reverse osmosis, the remaining concentrated whey solid could be economically shipped to larger plants for drying.

The importance of reverse osmosis to the cheese-making industry may be revealed by a series of statistics. Each year, over 22 billion pounds of whey are produced in the United States. This "liquid" whey contains about 93.5 percent water. A plastic membrane only 1/10 micron thick (.000004 inches) is sufficient for the osmosis process. For a cheese plant processing 150,000 pounds of milk daily, approximately 15,000 pounds of cheese are produced. Space requirements for a reverse osmosis "unit" would be only 10 to 20 cubic feet. This unit is capable of reducing the 135,000 pounds of liquid whey to 9,450 pounds of solids in a concentrated solution.

What use could be made of the salvaged whey? Dried whey not only improves the nutritional value of foods, it also introduces other desirable qualities. When whey is an ingredient in enriched white bread, it gives the toasted product a golden hue. In addition to bakery goods, whey also contributes wholesome properties to frozen vegetables, sour cream sauces, soups, candy, cookies, frozen cream pies, and frozen macaroni and cheese. Diverse beneficiaries include ice popsickles, frozen fish sticks, and even instant western omelets.

With the severe food shortages in many developing countries, dried whey could easily become a valuable addition to United States aid programs. Scientists are currently searching for the best ways to adapt whey to the diet of children in the Far East and in South America. In India, dried whey mixed with soybean powder is being tested as a baby food. "Reverse osmosis," a tongue-twister in English, may prove to be easily translated into foreign tongues, to the ultimate benefit of all mankind.

Reclaiming Olive Brine

It has been estimated that nine of California's large olive processing plants alone discharge over 200 million gallons of briny waste yearly. Olive processing demands several treatments with a salt and lye solution. Like other fruits and vegetables, olives, in turn, release sugars and a variety of other organic compounds into the processing liquids. These contaminants render the liquids unfit for further use.

Scientists have devised a method to remove the contaminants from the brine by forcing used processing liquids through columns of activated carbon. The brine solution is reusable. Practical application on an industry-wide basis could reduce pollution by 50 percent. Economy, compared with other anti-pollution methods being investigated by the scientists, will determine its acceptance and implementation by the olive-processing industry.

A demonstration pilot plant for cleaning and reusing olive brine by the ARS method has recently been erected in Lindsay, Calif. This commercial-scale operation has been made possible through the cooperation of the National Canners Association and the financial support of the Federal Water Quality Administration. It is hoped that this process may be extended to include brines from pickles, cherries, and sauerkraut.

Pickling in the Can

The principal pollutant from pickle plants is the brine produced during fer-

mentation and finishing. Quantitatively, it is the accumulation of this brine that creates an enormous disposal problem. In the old method, unwashed cucumbers were subjected to brine treatment during vat fermentation and again when inserted into the individual jars and cans to be sold to the consumer.

A simple, yet ingenious process solves the problem. The solution: pickle in the jar to be sold instead of in a vat. By this new process, cucumbers and other vegetables to be pickled are first washed. Next, they are treated with heat and placed in cans or jars with "sterile" brine, with spices, and with a small amount of a culture that produces lactic acid. Fermentation in the vat has been successfully bypassed.

The containers are then sealed, and fermentation takes place within the individual cans. No repackaging is necessary. The pure culture of organisms present in the containers provides the type of fermentation desired and the bulk accumulation is avoided. Purchased by consumers, the individual cans and the pickle brine will be discarded on a household by household basis.

Processing Tomatoes On the Spot

The current practice of hauling tomatoes to the cannery for processing presents a gigantic waste removal problem. As they accumulate, large volumes of tomatoes mean large volumes of skin, seeds, and pulp. The water used to clean and process these tomatoes carries away this debris, only to transfer the problem to regions far downstream.

Why not process the tomatoes in the field and save time, money, and waste instead? This idea was translated by scientists into a new approach. By using a trailer-mounted tomato preprocessing unit, the center of activity was transferred from cannery to growing area. All except the final steps of processing can now be completed in the field.

Tomatoes are first brought to field stations in the farming areas where pulp, skin, stems, leaves, and all other waste matter are separated. Wash waters may be funneled into irrigation canals. Solid wastes can be returned to the land and spread over the fields. Distributed over a wide area, the relatively small volume of field station waste would not constitute a pollution problem.

In the meantime, the juice is conveyed to central processing plants for canning or for concentration into catsup or other subsidiary products such as sauces or purees. The only effluent from the central plant is the pure water evaporated from juice during the manufacturing process.

Besides reducing pollution, field preprocessing unit benefits the tomato-processing industry in related ways. Tomatoes bruised by mechanical harvesting equipment spoil or are crushed during long hauls from field to cannery. This loss may reach as high as 10 to 20 percent of the harvested crop. Eliminating this loss is of major economic significance to the entire industry.

There is yet another bonus. This experimental tomato-peeling process consists of heat application by steam injection and adjustment of acidity prior to juice extraction. This permits greater efficiency in food recovery from tomatoes. It also produces the finest consistency of juice and concentrated products. The National Canners Association is currently cooperating in this research by conducting surveys to compare the new process with conventional methods.

Saving Soybean Solids

Over the years, soybeans have evolved into one of the most profitable agricultural staples. But in conventional soybean oil processing, the free fatty acids are absorbed into the water needed during

washing operations. Refining plants have been disposing of about 150 million gallons of this alkaline washwater annually.

Science has successfully designed a new system for soybean processing. This method is capable not only of preventing pollution but also of conserving water. In the experimental process, the acidified washwater is forced through resin which absorbs acids and is then recirculated. This recirculation step can be accomplished through many cycles. Contaminants are removed, and the same water may be used again and again.

The only fresh water required is as a replacement for the amount lost through evaporation. One benefit is the elimination of emulsified oil. Another bonus is the recovery of a small amount of a usable byproduct, soy fatty acids. When recovered, these acids have a market value between 5 and 10 cents a pound to companies that manufacture industrial derivatives. Soy fatty acids may appear as an ingredient of high-quality soaps, rubber products, even jet aircraft lubricants.

Some soybean processors have still another kind of pollution problem. When they manufacture protein concentrates and other compounds, one byproduct is a very dilute solution called soybean whey. Estimates predict that 20 million pounds

Tomatoes ready for their first bath at the field station. The relatively small volume of wash water may be returned to the land through irrigation canals.

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of solids could be recovered from these dilute solutions yearly.

Some processors concentrate this whey and use it in feed. Others simply dispose of it as best they can. But a method to make better use of the nutrients in soybean whey is presently being studied by scientists at Peoria, Ill.

In the process, some of the protein is coagulated protein is high in tryptophan becomes separated. The remaining solids are then concentrated. This heat-coagulated protein is high in tryptophan and lysine; the remaining solids boast large amounts of the sulfur-containing amino acids, cystine and methionine.

Cystine, lysine, methionine, and tryptophan are all essential amino acids. The whey proteins, along with other solids, can be used to improve the protein quality of foods. Still another method has been found that could transform a product formerly "lost" down the drain into a valuable, useful food.

Recycling Food Processing Wastes

A qualified, but positive answer to the growing pollution in our environment lies in recycling food-processing wastes. A start has been made to devise methods to transform food wastes into new food products.

Consider the alternatives. The failure to provide a solution to this type of waste problem in the past has made pollutants out of potential food products. Today, there is an environmental urgency for some immediate, remedial action.

Recycling food processing wastes, of course, will not prove to be the complete answer to the pollution problem. A good start has been made. It will continue, and with proper guidance, will ultimately reduce our waste problem significantly. ■

New Ways To Fight Pests: Alternatives to Pesticides

GOOD INSECTS that eat bad insects and weeds . . . Plants that protect themselves from pests . . . Chemicals that lure insects to their death . . .

Predators and parasites, resistant plants, and insect attractants can do these things. No panacea, but they are proving effective as biological methods of pest control—alternatives to pesticides that can be safer, cheaper, and more efficient than pesticides now being used.

Scientists are searching for new ways to control pests—insects, plant diseases, and weeds that threaten man's health and food supply. In cooperation with industrial, State, and other Federal staff, they conduct research to develop effective pest-control methods that will not pollute the environment. Some of the alternatives are already being used by farmers and homeowners; others are being tested or are still in the laboratory stage.

Some of the general classes of alternative methods, how they work, and the pests they protect against, are as follows:

Predators, parasites, and **pathogens** (disease-causing organisms) destroy insects and weeds by feeding on or infecting them.

Resistant varieties of plants inhibit attack by insects, diseases, and nematodes (tiny worms).

Attractants lure insects to traps or other devices where they can be killed or sterilized.

Genetic control consists of releases of sexually sterile insects that mate with normal insects.

Bioenvironmental controls are cultural and mechanical practices against insects, nematodes, weeds, and diseases.

Hormone and **daylength manipulation** disrupt an insect's life cycle and limit the number of insects that survive.

Predators, Parasites, and Pathogens

Not all insects are considered pests of man. In fact, agricultural scientists have found ways to make insects work for man. This is often one of time—and patience—in getting these "friendly" predators, parasites, and pathogens established and working for man. It may take 10 or more years.

A tiny flea beetle with fastidious taste is helping to rid the Southeast of alligatorweed, an aquatic weed that clogs waterways. Aquatic weeds are not only a nuisance; they are dangerous as well. They foul propellers on boats, they can harbor diseases, and swimmers can drown if they become entangled in them. Alligatorweed can be controlled with herbicides, but heavy, frequent applications are necessary.

"Insect explorers" went to South America, where they found tiny beetles that feed only on alligatorweed. After

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A parasitic wasp lays her eggs in a cabbage looper caterpillar. When the eggs hatch, the young wasps will devour the cabbage looper.

extensive tests to make sure the beetles would not harm man, animals, or desirable plants, scientists released them into clogged waterways in Georgia, Florida, and Mississippi. The beetles have multiplied and now help control alligatorweed in some areas from North Carolina to Texas.

In addition to the use of insects to control aquatic weeds, plant-eating fish, such as the White Amur, and snails, such as the Marisa, show good potential for bio-control of water weeds. This possibility is being studied intensively by ARS scientists.

Insect predators and parasites work for man by feeding on harmful insects and weeds; pathogens are micro-organisms that cause diseases. Nearly every pest is attacked by predators, parasites, or pathogens in nature. Very often, however, enough of the pests survive to damage crops. Furthermore, when pests are accidentally brought to the United States from other countries they almost always leave their natural enemies behind.

For example, the alfalfa weevil, an introduced pest, requires the application of insecticides for its control in the United States. In its native Europe, however, it is controlled primarily by tiny parasitic wasps. In 1957, scientists in the Department began importing these parasites and releasing them in weevil-infested alfalfa fields in Eastern United States.

By 1969—12 years later—the parasites had spread and controlled the weevils to the extent that farmers in New Jeresy that year did not need to apply pesticides to protect their alfalfa. The parasites are spreading rapidly and by 1980 could control the weevil in many other areas of the nation.

In the Northeast, the pathogen that causes milky spore disease has long been used to fight the Japanese beetle. Community-wide applications of dust that contains the milky spore bacterium have greatly reduced the damage caused by the beetle. And once established, the disease reduces the need for pesticides.

Another bacterium, *Bacillus thuringiensis,* attacks many kinds of moth larvae. Moth larvae, or caterpillars, feed on many kinds of plants, and can be very destructive. For example, the cabbage looper feeds on cabbage, lettuce, and many other crops. But, when infested

plants are sprayed with the pathogen, cabbage looper caterpillars stop their feeding in a matter of minutes. Soon after, they die.

Many insects are susceptible to virus diseases. The bollworm and the tobacco budworm, destroyers of cotton, corn, tomatoes, and other crops, are attacked by a virus being studied by scientists at the Pink Bollworm Laboratory, Brownsville, Texas. Commercial companies are now developing ways to produce the virus in quantity.

Scientists have also discovered a virus that attacks larvae of the codling moth, the cause of "wormy" apples. They are also studying diseases of house flies and mosquitoes.

Most insect pathogens are able to infect only their specific insect hosts and are not active against other species. So far, all of those investigated are harmless to man, animals, and beneficial insects.

Scientists are trying to find out more about how pathogens work and spread, and how to produce and use them in quantity. Scientists also want to speed up the course of the diseases so that the insects die before they can damage crops.

Resistant Varieties

Juicy tomatoes and crisp green peppers from your garden—with little or no use of pesticides? Genetic resistance makes it possible.

Porte and Enterpriser, tomato varieties developed by agricultural scientists, are resistant to verticillium and fusarium wilts. Peppers resistant to the pepper weevil and several species of nematodes are also available. In a few years, tomatoes resistant to four diseases, spider mites, and aphids will be ready for planting by farmers and home gardeners.

Resistance has two major drawbacks: Usually, many years are requred to develop it in a commercially acceptable plant—and new strains of insects or pathogens develop to which "resistant" plants no longer resist. Otherwise, it is a nearly ideal method of controlling insects, diseases, and nematodes. Resistant plants are safe, cheap, and practical. They do not cause pollution, can greatly reduce the need for pesticides, and usually cost the grower no more than susceptible varieties.

Nematologists and plant breeders have made progress in developing nematode-resistant plants. A number of new varieties are released each year. Resistance to one or more species of nematodes has been developed for tobacco, cotton, bermudagrass, tomatoes, soybeans, lespedeza, vetch, alfalfa, pole beans, lima beans, sweetpotatoes, potatoes, peas, peppers, cantaloup, citrus fruits, peaches,

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Resistance can protect crops from damage. Right, *soybeans resistant to the soybean cyst nematode;* left, *a susceptible variety.*

and grapes.

Use of these nematode-resistant varieties has greatly reduced losses in yield and quality. But many added varieties are needed to reduce losses caused by other nematodes.

Resistant plants, when exposed to specific insects, diseases, and nematodes, may lack attractiveness or may be tolerant—that is, they can suffer damage without being killed. Some have physical characteristics that prevent an insect from feeding or laying eggs on them. Others are toxic to an insect, nematode, or disease organism.

How is a resistant variety developed? Plant breeding is a slow, complex process—one that takes special scientific knowledge and years of experimentation. Thorough studies must be made of many species, including methods of reproduction and resistance to pests and diseases. Finally when a promising variety emerges it must be tested adequately for its range of adaptation and cultural requirements. Then seed stock must be increased and maintained.

Basically, scientists use three methods to develop a resistant variety: (1) They import foreign plant materials that already have resistance. (2) They expose many generations of native plants to insects, diseases, or nematodes, and use the least-damaged plants for breeding stock. Or (3) they cross both introduced and domestic wild plants that have resistance with susceptible commercial varieties.

To illustrate, more than 500 varieties of pears were tested for resistance to fire blight, a disease that kills the trees. Several have resistance. The resistant pears cannot be used, however, because presently their fruit is only about the size of a cherry seed.

Now, plant breeders are crossing the resistant pears with large-fruited varieties. So far, they have produced two new varieties—Magness and Moonglow—which are somewhat resistant. In a few years, scientists hope to have more completely resistant varieties.

Widespread use of resistant varieties can practically eliminate pest problems. This has already occurred with the spotted alfalfa aphid, several wheat diseases, and the hessian fly. In the Midwest, the hessian fly used to destroy wheat. Few insecticides were effective against it. Farmers could partially control it by delaying the planting of wheat (see “Bioenvironmental Controls” (p. —), but this reduced the value of the crop in some areas. Today, however, resistant varieties of wheat are grown on 10 million acres, and the hessian fly is no longer a major problem.

The wheat stem fly is also controlled almost entirely by resistant varieties, and losses to the European corn borer, and the corn earworm are greatly reduced by growing varieties partially resistant to these pests.

A major goal of plant breeders is to develop multiple-pest resistant varieties—that is, resistance to several diseases, nematodes, and insects in a single plant. Multiple-pest resistance can reduce the need for pesticides on a crop. Potatoes developed by scientists are resistant to six diseases and to the potato leafhopper. “Mars,” a tomato variety for commercial growers, is resistant to three diseases. Alfalfa resistant to the pea aphid, spotted alfalfa aphid, and potato leafhopper has been developed. Plant breeders are working on cotton with combined resistance to the boll weevil, the cotton fleahopper, and the bollworm.

The job of the scientists does not end with a new variety, however. Insects and diseases can sometimes adapt to a resistant variety and continue to damage it. So, the scientists are constantly trying to keep a step ahead of the pest.

Attractants

Science is using natural attractants to help control harmful insects.

Trap baited with attractant for cabbage loopers.

Blacklight trap used to attract cabbage looper moths. This trap is also baited with manmade sex attractant to enhance its effectiveness.

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Insects respond to various chemical substances in plants in their search for food and to chemical sex attractants produced by the insect for mating. They also respond to light and sound. Attractants are used by scientists to lure insects in traps or other places where they can be killed.

Live, unmated female insects can be put inside traps to attract the males, or, in some species, male insects are put in to attract the females. Once inside a trap, the insects are killed with an insecticide, or, in other traps, they become caught in a sticky substance and cannot escape.

Scientists are devoting considerable research effort toward isolating, determining the chemical structure, and synthesizing sex attractants in order to obtain large enough quantities for use in practical tests for control of several major insect pests.

One of the most powerful attractants is methyl eugenol, a commercially available chemical, which attracts male oriental fruit flies. It is not a sex attractant; it attracts the males for feeding rather than for mating.

Methyl eugenol was used to eradicate the oriental fruit fly from the islands of Rota, Tinian, and Saipan in the South Pacific. First, scientists fortified the methyl eugenol with a small amount of insecticide and put the mixture into small squares of fiberboard. Then, they dropped the squares from an airplane at a rate of 125 per square mile. About a dozen drops were made over a period of several months.

The male flies were highly attracted to the methyl eugenol, and when they landed on the fiberboard, they were killed by the insecticide. As a result, in a few months, only female flies were left on the islands. Their eggs, which had not been fertilized, did not hatch. And when the females died, the islands were free of the pest.

Materials for the project cost about 50

cents an acre. Only about one-tenth of an ounce of insecticide per acre was applied. Formerly, growers applied 3 pounds of insecticide to each acre every year for seasonal control of this pest.

Workers also use methyl eugenol as a quarantine measure to help detect and get rid of oriental fruit flies that may enter the United States in infested fruits and vegetables carried by incoming travelers or by hitchhiking on commercial and military aircraft and ships. Traps that contain methyl eugenol are placed near ports of entry to intercept new infestations.

When oriental fruit flies were found recently in Los Angeles County, California, a mixture of insecticide and methyl eugenol was applied to the trunks of citrus and other trees in the infested area. The insect was soon eradicated.

Scientists have also developed an attractant for yellow jackets. If it proves successful, it could be a boon to campers and picnickers because it can lure the yellow jackets into a trap and away from recreational areas.

Many insects are attracted to specific kinds of light. Blacklight—another name for ultraviolet light—attracts many kinds of insects, such as the pink bollworm, cabbage looper, tobacco budworm, and tobacco hornworm moths. Agricultural scientists in North Carolina found that three blacklight traps per square mile, combined with cultural control, greatly reduced the need for insecticides for control of the tobacco hornworm.

Scientists are conducting field tests using light traps to control the hickory shuckworm on pecans. Pecan growers now apply insecticides eight to ten times a year to control the shuckworms and other pests. The insecticides kill off predators and parasites of aphids that attack the pecans. Thus, elimination of chemical control for the shuckworms would encourage beneficial insects as well.

Genetic Control

Scientists are taking advantage of mating habits to get rid of harmful insects. Genetic control was used to eradicate the screwworm fly, a killer of livestock, from the Southeast and to control it in the Southwest and Northern Mexico. Genetic control is also helping to keep the pink bollworm, a pest of cotton, from spreading in California.

The best known example of genetic control is the sterile male technique. In applying this method, scientists first reduce the native population of insects with cultural control, pesticides, or other methods.

Meanwhile, insects are reared in the laboratory and the males are sterilized with radiation from radioactive cobalt or cesium or with sterilizing chemicals called chemosterilants.

The sterilized insects are then released in an infested area—many sterile insects to each male insect in the natural population. When the normal female insects mate with sterilized males, they do not produce young. Sterile male releases are continued and with each succeeding generation, fewer and fewer fertile matings take place. Eventually, the insect is eliminated as the older individuals die off and are not replaced by a younger generation.

In Washington State, scientists are using genetic control in an attempt to control the codling moth in part of the Columbia River Basin. The codling moth is the most destructive pest of apples in the United States.

First, insecticides are being applied to reduce the number of codling moths. Old apple trees in abandoned orchards—a possible hiding place for the insects—are being destroyed.

In the meantime, scientists are developing a pilot codling moth program in the Wenas Valley of Washington. A 25-square-mile area, comprising some 400 acres of commercially grown apples

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Scientist uses ice water to separate mosquito pupae, which sink from the larvae floating on top of the water. The pupae will be sterilized for use in genetic control.

and pears, will be the testing ground for the project. Scientists will rear and sterilize the males to be released to mate with fertile females in 1971.

Also, if insecticides were not used against the codling moth, natural enemies of mites, aphids, and other pests would multiply to help control these pests. Ultimately, few chemicals would be needed except to control sporadic outbreaks of insects in localized areas.

The release of sterile Mexican fruit flies instead of a spray program is being used in Northern Mexico to prevent establishment of this pest in southern California. Genetic control is also being studied as a possible measure for suppressing certain species of mosquitoes in parts of Florida.

Scientists are also using genetics to breed insects that can pass on inferior traits to their offspring. Such strains of insects might produce fewer offspring, for example. House flies, boll weevils, and some kinds of mosquitoes are candidates for this method.

Bioenvironmental Controls

Stalk-cutting and disposal of parts of plants left in fields after harvest has become standard practice for many crops. For example, if tobacco growers cut and dispose of stalks in the field the hornworms and other insects that live through the winter in the stalks and attack the crop the following year are drastically reduced.

This is an example of bioenvironmental control, which may include cultural and mechanical methods—some old, some new. Here are a few other examples that will at least play a part in reducing the overall needs for pesticides.

In a new 3-year study in Maine, agricultural scientists strive to cut use of pesticides in the control of the green peach aphid, the primary carrier of potato leaf roll disease, a destructive virus. They hope to do this by removing wild Canada plum thickets where the aphids overwinter.

To control potato leaf roll in the Columbia River Basin, scientists applied insecticides to peach trees in commercial and home orchards instead of to the potatoes. In this area, the green peach aphid, which transmits this disease, spends the winter only on peach trees. A single spraying with insecticides on the few thousand peach trees in the area reduced by 95 percent the aphids that attacked 60 thousand acres of potatoes.

In Washington State, the aphids carry yellows disease of sugar beets. Scientists discovered that the aphids remain active during the winter on weeds near warm water in drainage ditches. The scientists showed farmers that they could control the aphids by burning the ditches each winter. This control method greatly decreased the farmers' need for insecticides, saved money, and increased yields by 2½ tons per acre.

In the Southwest, the pink bollworm is a major threat. It infests much of Oklahoma, Texas, New Mexico, and Arizona. It also infests the Imperial and Coachella Valleys of California, and threatens to enter the San Joaquin Valley, the principal cotton-producing area of the state. To control the pink bollworm, scientists recommend that farmers grow varieties of cotton that mature early, and after harvest destroy the stalks in the field. Many of the pink bollworms then die for lack of food. This method has been effectively practiced by farmers in Texas for many years.

Other insects can be controlled in field crops by delaying planting until after insects have passed their most destructive stage.

Cotton root rot can be controlled by plowing the soil deeply and mixing it thoroughly before planting. This process leaves few of the disease organisms in the upper layers of soil where they can infect plants.

Marigolds contain a substance in their roots that kills many kinds of nematodes, tiny soil worms that feed on the roots of plants. When the marigolds are planted in rotation with other crops, they can cut the need for pesticides to control the nematodes. Other rotation crops, such as hairy indigo, crotolaria, and velvet beans are also highly effective in controlling many nematodes.

Fusarium root rot in dry beans can be controlled by first planting corn in the field. After the corn is harvested, the stalks are plowed under. The stalks then give off a chemical that destroys the disease organisms before they can attack the later crop of beans. In most areas where several crops are grown, rotations that include non-host crops and resistant varieties can be used that reduce most losses caused by nematodes.

One of the most destructive diseases of peas is *Aphanomyces* root rot. No pesticides control it effectively, and no varieties have been found resistant to it.

However, scientists discovered that crucifers (plants in the cabbage family) control the disease when they are added to the soil and allowed to decompose. The crucifers give off sulfides—the same chemicals that give rotten eggs their unpleasant odor. These chemicals are poisonous to the nematodes, but are highly volatile—that is, non-persistent. And since they are produced in small amounts and are in the soil, they pose no harm to man or animals. Scientists are now conducting field tests to check the effectiveness of both cabbage sulfides and man-made sulfides in controlling disease.

Roots of tobacco and other crops and weeds can be plowed up after harvest, and literally kill millions of nematodes because they starve in late summer without roots to feed on.

In the Southwest, nematologists recently have shown that fallowing land (growing no crops) for 2 to 3 months during summer provides nematode control for the next crop equal to soil fumigation with nematicides.

Many nonchemical means of controlling weeds have been developed, research is continuing to improve these and discover others.

Some specific examples of bioenvironmental control of weeds follow:

- Flame cultivation for control of weeds in cotton.
- Cross cultivation for control of weeds in cotton, corn, and soybeans.
- Intensive fallowing for control of johnsongrass.
- Crop rotations for control of problem weeds such as nutsedge or red rice.
- Improved cultural practices, including use of herbicides, that result in vigorous unbroken stands of crops to alleviate the need for late-season use of herbicides in cotton, soybeans, and sugar beets.
- Use of the rotary-hoe and other types of postemergence cultivation for control of weeds.

Hormone and Daylength Manipulation

Turning insects into "freaks" is a new challenge for agricultural scientists. Scientists now know how—at least on a laboratory scale—to reorder an insect's life cycle so it becomes a "freak" that cannot survive or reproduce.

Insects, like plants and other animals, have hormones that help to regulate their body functions. Presence of juvenile hormones in an insect's body makes it grow but not mature. Absence of juvenile hormones allows a young insect to become an adult. If insects get doses of juvenile hormones when they would normally mature, they do not complete their development to the adult stage. These insects are "freaks"—half larva, half adult, that cannot function normally.

Scientists have found substances similar to the juvenile hormone and other hormones in some plants on which the insects feed. The presence of these sub-

stances in certain plants might explain why some varieties are resistant to insect attack.

Manipulation of daylength is another way to interfere with an insect's life cycle. Scientists have shown that exposing young corn earworms to a longer period of light than normal in the fall can prevent them from entering diapause, their winter resting condition.

During diapause, an insect's life processes slow down and require little nourishment. In most parts of the United States, if insects did not enter diapause in the fall, they would freeze or starve for lack of food in cold weather.

Integrated Control

Foreign parasites and predators that will not survive here . . . Insects and diseases that adapt to resistant plants . . . Insect attractants that have complex chemical structures that are difficult to duplicate in a test tube . . . These are a few of the challenges facing pest-control scientists. No one method can control every insect, weed, nematode, and plant disease. And frequently, it takes a combination of methods to control a single pest. So scientists are working on combinations of new and older methods, combinations known as integrated control.

In the Mississippi Delta, agricultural scientists will integrate several methods of control in a pilot experiment to try to eradicate the boll weevil, the South's costliest cotton pest. Farmers use more insecticide for control of the boll weevil than for any other insect.

Beginning in August 1971, scientists will use bioenvironmental control, attractants, genetic control, and carefully selected insecticide applications in a practical test against the boll weevil on about 100 square miles of Delta farmland. If successful, they believe that a full-scale program could eventually be used to banish the boll weevil from the entire Cotton Belt.

Integrated control techniques are also used to combat weed problems. Weed scientists are developing combinations of mechanical, biological, and chemical measures for controlling pernicious weeds, such as johnsongrass, nutsedge, bindweed, and cocklebur. For example, integrated practices to control johnsongrass include mechanical preplant cultivations, postemergence flame cultivation, cross cultivation, crop rotations, and judicious use of herbicides. Farmers are already using a number of integrated measures on a routine basis.

A promising start has been made. But many added integrated control techniques are needed.

Expensive? Yes. But compared to the cost of pesticides, applied every year, integrated control is a bargain, indeed. And in reducing pollution and safeguarding the health of man and animals, the alternative methods will continue to pay dividends to future generations. ■

A Green World . . .
A Clean World

Man is changing the environment by removing trees and other vegetation to make room for new roads, housing, airports, and shopping centers—the demands of an advanced civilization. For many years, experts have pointed out the dangers of such "progress." Even 60 years ago, Theodore Roosevelt warned that to skin the land would undermine the very prosperity we seek for our children.

Much has been written about the effects of air pollution in our cities, but air pollution is also affecting agriculture. In some sections of the country, air pollution is a greater threat to the farmer than adverse weather or pests.

Carbon monoxide, the most common pollutant in urban air, is toxic to humans and animals. It comes from the burning of any carbon material, but mainly is spewn into the atmosphere from motor vehicles.

Some common pollutants that are toxic to plants are ozone and peroxyacetyl nitrate (PAN), formed by action of sunlight on exhaust fumes, and sulphur dioxide, which results from the burning of fossil (coal, oil) fuels.

Far too many people have ignored the warnings. Now we wonder: Is there an alternative course?

Challenge to Science

Our survival depends on protecting the environment. The benefits of vegetation are generally recognized, and one of the challenges to scientists in agricultural research is to keep the landscape green.

These scientists are concerned with the use of trees, turf, ornamentals, and related plants in protecting five environments: urban, suburban, transitional (areas that connect city and country), controlled (enclosed malls, offices, museums, etc.), and rural.

In the urban environment, for example, the concrete canyons of our cities are difficult areas for sustaining plant life. Building construction has lowered water tables; the air is polluted; the earth is compacted; much of the rainwater is lost because most of the ground surface is paved; salt used for snow and ice removal in winter seeps into the ground; tall buildings block sunlight; and underground utility lines such as gas and electric, may interfere with tree roots. We are looking for plants adapted to these adverse conditions.

In controlled environments, artificial light must be used to grow greenery. Scientists are trying to define optimum conditions for plant growth. Special emphasis is on the best use of artificial light in growing plants. This is important in growing plants in malls and enclosed environments such as public buildings and homes. Other problems associated with growing plants in artificial conditions are low humidity and compaction of soil.

Active research is underway on air-

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An ideal environment: Moisture, sound, and temperature are controlled by plants in this Japanese setting.

pollution damage to ornamentals, on the role of trees in removing pollutants from the air, and on the development of pollutant-tolerant ornamentals.

Nature's Air Conditioning

Plants are one of the most effective air fresheners in existence—they are a natural source of air conditioning. Human life depends on air, of which 21 percent is oxygen. Man inhales oxygen and exhales carbon dioxide; then plants use this carbon dioxide in photosynthesis releasing oxygen in the process. Oxygen comes primarily from green plants; hence, the great interdependence between plants and man.

Plants condition our atmosphere in other ways too. They change temperature, moisture content, and airflow. They absorb and filter out large amounts of soot, dust, pollen, smoke, offensive odors, and fumes. Air conditioning by plants is accomplished by precipitation, dilution, deodorizing, and air-cleansing.

Precipitation refers to the removal of airborne particles by leaves. The hairiness and moisture on leaves trap or absorb the dust particles and hold them until they are washed down around the roots of the plants by rain.

Dilution occurs when polluted air is mixed with the uncontaminated air released by plants.

Deodorizing is the masking of unpleasant odors with the pleasing fragrance of blossoms such as honeysuckle, jasmine, and mock-orange.

Air-cleansing is the absorption and accumulation of gaseous contaminants by plants. In absorbing the pollutants, plants are usually injured, but they continue to absorb the toxic gases as long as functioning leaf tissue remains. Evergreen-type plants may function year around because their leaves remain green.

Finally, trees cool the air just by shading. They are welcome additions to our yards and to hot city streets.

Noise Abatement

Noise is all around us: from transportation, construction, power mowers and other equipment, industry—and people. Excessive noise can adversely affect our mental and physical health.

Plants help muffle noise by deflection and absorption. This is of particular interest to owners of property along a highway or near industry.

A belt of trees between a residential and industrial area will absorb and filter some of the noise. For this purpose, a combination of trees and shrubs of dense texture is most effective. Even grass helps to lessen the din.

Since "noise pollution" is a year-round problem, evergreens should be considered.

Erosion Control

When the earth is denuded by construction in rapidly developing areas, soil erosion is a dangerous by-product. Trouble begins when bulldozers strip the cover from thousands of acres to make room for new highways, shopping centers, and housing developments.

The best way to stop moving soil is to cover it with vegetation. For this purpose, scientists look for plants that grow quickly; that are resistant to pollutants and disease; and that are hardy and economical.

Grass is commonly used to control erosion, but legumes, cover crops, flowers, and shrubs are also effective.

Specialists are trying to breed grass species adapted to all environmental conditions; to find the most economical way to control insects, diseases, and weeds; and to develop management practices that will provide beautiful turf.

In addition, limited studies are being conducted on improving turfgrasses for

home lawns, roadsides, cemeteries, and airports; and for parks, playgrounds, golf courses, and other recreational areas. To maintain a pleasing, uniform grass cover requires use of adapted grass varieties.

Improved bermudagrass varieties, developed and evaluated by ARS, are popular in Southern United States.

Tall fescue, an important forage grass, is presently being tested for soil-erosion control. This coarse grass is often grown on athletic areas, parks, and roadsides and is considered wear resistant. It is tolerant to poor drainage and shade, and to some disease and insect pests.

Tall fescue is popular in many parts of California because it persists through hot summers and cool winters year after year. The variety called "Kentucky 31" is best adapted to Eastern United States. It is a durable grass in the transition areas of the United States where neither cool-season grasses (Kentucky bluegrass, red fescue, and bentgrass) nor the warm-season grasses (zoysia and bermudagrasses) are especially well adapted for lawns and turf.

Ground covers include a wide range of low-growing annual and perennial plants that can substitute for grass. They provide a pleasing landscape effect through color and form. Selection of ground covers and methods of planting vary from region to region. Broad-leaved evergreens are most frequently used, but coniferous and deciduous plants are also suitable.

Iris and daylilies have stopped erosion along new highways in Georgia. Crownvetch is a pink-flowered legume adapted to the humid northern portion of the U.S. south to a line drawn from North Carolina to eastern Oklahoma. It can also be grown successfully in much of Western United States where adequate water is available.

Other commonly grown ground covers are ground-ivy, iceplant, memorial rose, periwinkle, and pachysandra.

Because soil conditions along highways vary more than natural conditions in the surrounding area, particular knowledge is necessary in choosing, establishing, and maintaining the vegetation for erosion control. A rare species of potentilla has been developed as highly suitable for roadside plantings in cold, dry areas of the northern Great Plains.

Plants for Safety

Planting along highways can help make them safer. A combination of trees and dense, vigorous shrubs is best to divide the two lanes of traffic. These plants could slow or even stop a car, if

Bermudagrass plots at Beltsville, Md. Researchers are trying to breed grass species that are better adapted to adverse environmental conditions.

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necessary, and are more attractive than fences.

Plants are grown on center strips and curves of roads to cut down headlight glare. For this purpose, evergreen shrubs are better than deciduous plants.

When chain link fences are used to divide highways, vines make them look better and also help to offset blinding headlight traffic.

In winter, snowdrifting can be very dangerous. Rugged shrubs are often used as snow fences to keep snow from blowing onto the roads.

Finally, an important reason for planting on highways is that plants lessen driver fatigue and accident proneness.

For specific road problems, landscape architects look for serviceable as well as beautiful trees and shrubs.

Windbreaks

Windbreaks are rows, or a single row, of trees and shrubs that are planted to shelter fields and homes. In farm areas, windbreaks are a protection against soil erosion and wind, and against flooding that results from uneven snowmelt.

Farmers find that adequate windbreaks save fuel in heating their homes, and that cattle, when protected by trees and shrubs, eat better and gain more weight than cattle exposed to severe elements.

In addition, windbreaks protect garden crops from soil drifting, blow-down, drying up by hot winds, and loss of soil moisture. They also reduce damage from frost or sleet. Orchards are subjected to much the same damage, but the greatest benefits from windbreaks are in protecting orchard trees during pollination and preventing wind damage to ripening fruit.

In irrigated areas, windbreaks reduce water loss from evaporation. Moreover, properly planted and managed windbreaks distribute snow evenly over agricultural land, which helps in moisture conservation—especially in the northern and central Great Plains.

Windbreaks also act as snow fences in winter, helping to keep roads and highways open.

Plant Introduction

Plant explorers are continually looking for plants that can best tolerate manmade pollutants and, in turn, help improve our environment. We not only grow native plants but also hardy plants brought here from other countries.

In a plant exploration program (supported in part by Longwood Gardens, Kennett Square, Pa.), plant explorers introduce ornamental plants, shade trees, and flowering shrubs to this country from all over the world. Europe has been a source of plants since colonial times, and for many years, the Orient has also furnished plants that have been widely distributed.

Zoysia grass was introduced from Japan. Rhododendron species were sent here from the China-Burma border and from New Guinea. Many of these are being used today in breeding programs. A privet of superior hardiness from Yugoslavia proved popular in several rigorous climates including Cheyenne and Sheridan, Wyoming, and Sioux Falls, South Dakota. The collector deliberately selected a plant from a severely cold area. This privet was later named "Cheyenne."

Another successful introduction to the U.S. is the Bradford Pear tree developed from a wild pear tree found growing in the most desolate areas of China. The tree thrives in extreme conditions of drought and in abrupt changes of temperature. It grows successfully from upper New York State to northern Florida and west to the Pacific Coast States.

Recently, seedlings of a rare conifer were collected on an exploration to Taiwan. Other plants have come from Brazil, Australia, Nepal, Northern India and Sikkim, the USSR, and South Korea.

The plant exploration program brings plants into our country to meet the needs

These Bradford pear trees (bottom), in full bloom, were developed from a wild Chinese pear found growing under widely different conditions. The wild pear tree grew both in water (right) and in sterile, decomposed rock (left) in its native habitat.

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of plant breeders, nurserymen, landscape architects, and conservation specialists—among others. After quarantine and propagation, the plants are evaluated for potential functional and aesthetic use, selected for elite types, and then distributed to State Experiment Stations, nurseries, and private research institutions for further testing.

The introduction program is a continuous process for replenishing and improving our plant breeding stocks.

Air-Pollution Studies

At a modern Plant Air Pollution Laboratory at Beltsville, Maryland, scientists are investigating the nature of pollutant-caused injury to plants and identifying species resistant to pollutants.

The Laboratory is equipped with special fumigation chambers for growing and exposing plants to various types and amounts of pollutants. This allows the scientists to observe the effects of the

chemicals on the plants. In larger scale studies, greenhouses specially equipped with activated carbon filters enable the researchers to compare plants grown in almost pollution-free environments with those grown under conventional greenhouse conditions in unfiltered air.

These studies show that under the greenhouse conditions, growth may be suppressed as much as 50 percent on the most sensitive varieties of some crops. Some inhibition of growth may occur without visible injury. Moreover, susceptible plants are prematurely aged and weakened by polluted air.

Some of the plants already tested will be grown again during a different time of year to determine if the season of growth is significant.

In air-pollution studies on sycamore and American elm seedlings, the growth of sycamore in unfiltered air averaged only 75 percent of that grown in carbon-filtered air. Both types of plants were fumigated with ozone and sulphur dioxide, and American elm proved more tolerant than sycamore. The results of such studies indicate that breeding for resistance to these pollutants is feasible.

Once science establishes the reaction of major crop and ornamental species and varieties to particular pollutants, growers will be able to reduce losses by selecting crops best suited to withstand prevailing environmental conditions.

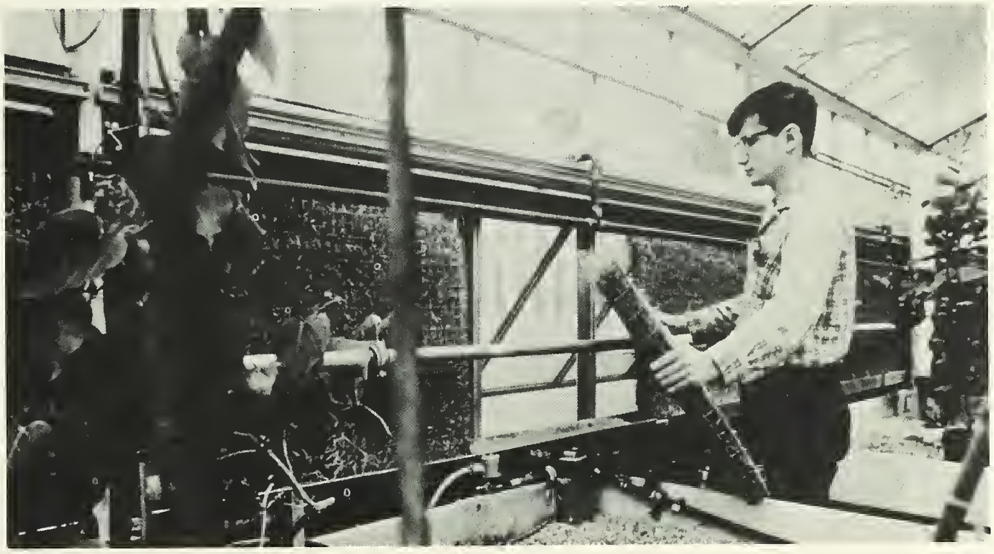
Other research on air pollution is underway at the Shade Tree and Ornamental Plants Laboratory, Delaware, Ohio. There, scientists are trying to find methods for evaluating the effectiveness of plants in removing pollutants and to determine which plants function best for pollutant removal.

ARS is cooperating in air-pollution research with the National Air Pollution Control Administration, Department of Health, Education, and Welfare, and the North Carolina Agricultural Experiment Station. At Raleigh, North Carolina, scientists are trying to determine the effects of air pollutants on plants, under controlled and ambient conditions, for use in development of air quality criteria.

City Trees

Trees are the dominant vegetation in man's immediate environment, so special attention is being given to improving the growth and health of urban trees.

The American elm is grown all over the nation exclusively for shade, but since



In air-pollution research at the Plant Air Pollution Laboratory, Beltsville, Md., pollution-free environments are created with activated carbon filters placed in walls of the greenhouses.

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Left: *Note the dwarfed radish and damaged leaves of a plant grown in polluted air.* Right: *This fully developed radish was grown in "clean" air.*

1930, it has been the victim of one of the most destructive shade-tree diseases in the U.S.—the Dutch elm disease.

At the Shade Tree and Ornamental Plants Laboratory in Delaware, research is directed toward finding an improved chemical control for Dutch elm disease—one that can be applied around the base of the tree. Also, trees are being developed that are resistant to Dutch elm disease, and we are now testing some varieties of American elm that are resistant.

The sycamore tree is heavily planted in cities, particularly in the East. Scientists at the National Arboretum, Washington, D.C., are developing a hybrid variety that will better resist air pollution.

Happiness is . . . Growing Lots of Plants

In a recent poll, people were asked to choose among 26 things they consider important to their happiness. Ninety-five percent wanted green grass and trees most—above their desires for good neighbors, modern kitchens, nearby shopping areas, or good schools.

Trees, ornamentals, and related plants are vital to the cityscape. They lend charm and psychological tranquility to cities that are becoming standardized, crowded, and dull.

We need green areas where people can get away from it all. Large or vest-pocket parks that interrupt the glass, concrete, and steel are oases—foes to "eye-pollution." Plants for these spots of relaxation should be chosen that enhance the setting and tolerate adverse metropolitan conditions.

Along highways, rest areas could be made more interesting with plantings that are selected, not only to prevent erosion, but also to hide objectionable views, provide shade, and create beauty. These plants should be quick-growing, dense in texture to absorb highway noise, hardy to foot traffic, and resistant to insects and disease.

* * * *

Wherever you have healthy green plants, you improve the quality of life. Why? Because vegetation keeps the air in better shape, and the landscape generally looks better.

Agricultural scientists are working with nature's own weapons to help protect and improve the environment. They hope the results of this research will be made available to everyone. ■

More Information on Managing our Environment

The USDA publications listed here offer a wide range of information on managing the environment. Some of the publications tell how science works with you in that purpose. Others will be useful in making your home surroundings more attractive as well as more comfortable; they include research-based facts on how to grow grass, ground covers, ornamentals, and trees.

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